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(54) Abstract Title
Control of pad dresser in chemical-mechanical polishing apparatus

(57) A chemical-mechanical polishing apparatus comprises a polishing pad, a rotatable polishing table, a wafer holder, a pad dresser, means for calculating the wafer polishing rate and a controller for controlling the dresser based upon the polishing rate. The pad is dressed each time after a specified predetermined number of wafers have been polished, this number preferably being one or two. The polishing rate can be calculated based on film thickness before and after polishing in combination with the polishing time or it can be calculated based on the current or power required to rotate the polishing table and the wafer holder in combination with the polishing time. Dressing time or dressing force can be controlled on this basis.

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FIG. 1

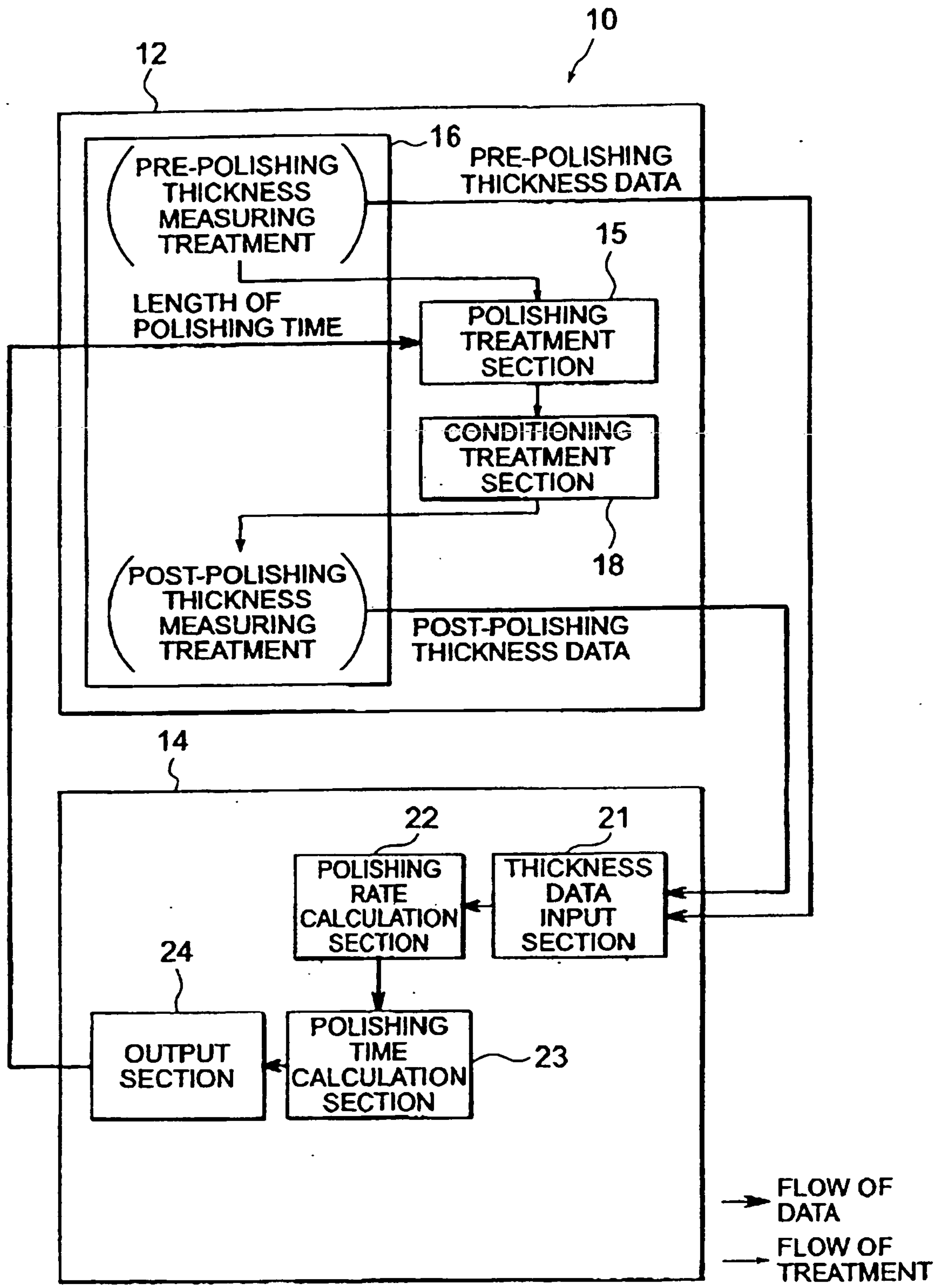

10
12
16
PRE-POLISHING THICKNESS MEASURING TREATMENT
PRE-POLISHING THICKNESS DATA
15
LENGTH OF POLISHING TIME
POLISHING TREATMENT SECTION
CONDITIONING TREATMENT SECTION
18
POST-POLISHING THICKNESS MEASURING TREATMENT
POST-POLISHING THICKNESS DATA
14
22
21
POLISHING RATE CALCULATION SECTION
THICKNESS DATA INPUT SECTION
24
OUTPUT SECTION
POLISHING TIME CALCULATION SECTION
23
FLOW OF DATA
FLOW OF TREATMENT

FIG. 2

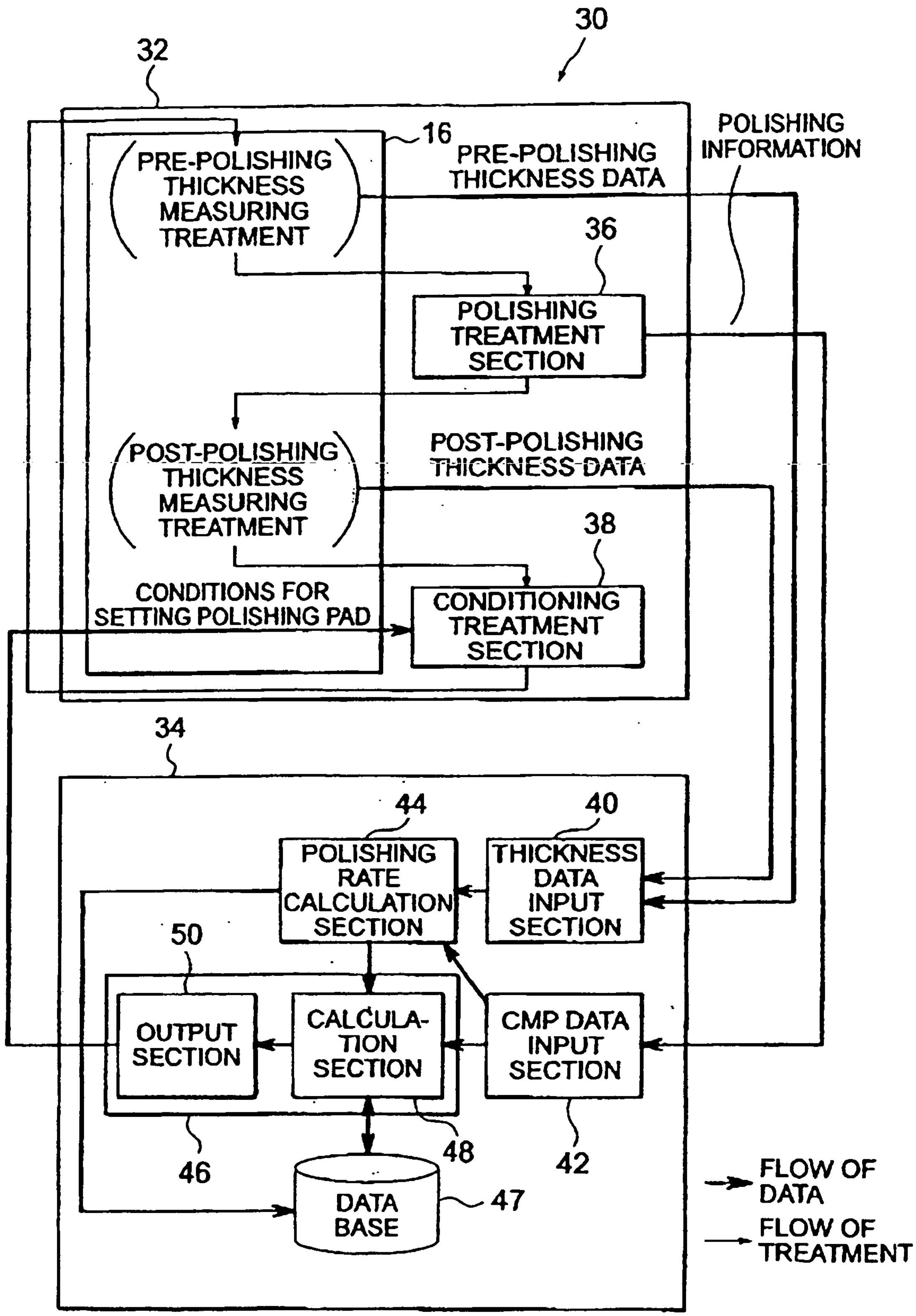

30
32
16
PRE-POLISHING THICKNESS MEASURING TREATMENT
PRE-POLISHING THICKNESS DATA
POLISHING INFORMATION
36
POLISHING TREATMENT SECTION
POST-POLISHING THICKNESS MEASURING TREATMENT
POST-POLISHING THICKNESS DATA
38
CONDITIONS FOR SETTING POLISHING PAD
CONDITIONING TREATMENT SECTION
34
44
POLISHING RATE CALCULATION SECTION
40
THICKNESS DATA INPUT SECTION
50
OUTPUT SECTION
CALCULATION SECTION
CMP DATA INPUT SECTION
46
48
42
DATA BASE
47
FLOW OF DATA
FLOW OF TREATMENT

FIG. 3

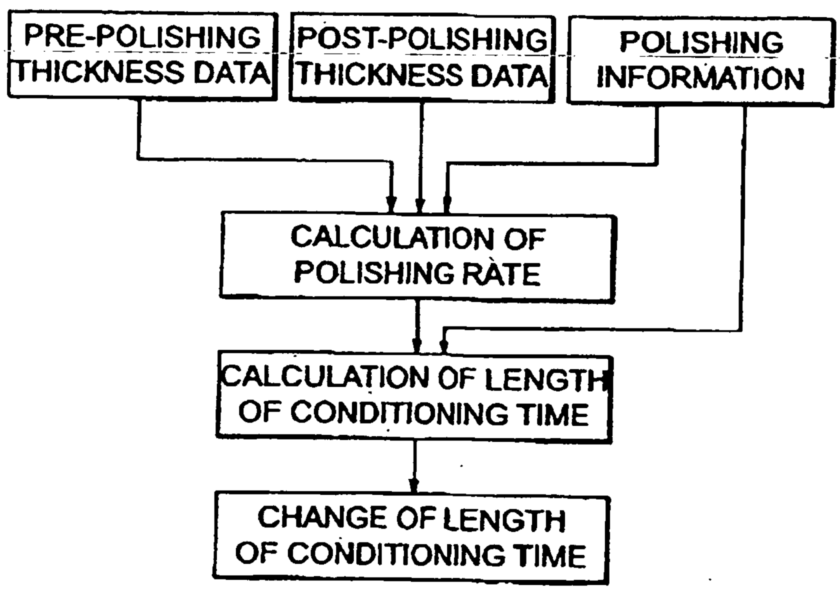

PRE-POLISHING THICKNESS DATA
POST-POLISHING THICKNESS DATA
POLISHING INFORMATION
CALCULATION OF POLISHING RATE
CALCULATION OF LENGTH OF CONDITIONING TIME
CHANGE OF LENGTH OF CONDITIONING TIME

FIG. 4

CONVERSION TABLES ARE SELECTED FROM DATA BASE BASED ON KIND OF FILM AND PRODUCT NAME

KIND OF FILM:OXIDE FILM 1,PRODUCT NAME:12345

CURRENT POLISHING RATE					
1600	80	75	70	65	60
1500	85	80	75	70	65
1400	90	85	80	75	70
1300	95	90	85	80	75
1200	100	95	90	85	80
1100	105	100	95	90	85
1000	110	105	100	95	90
	-100	-50	0	50	100

POLISHING RATE VARIATION AMOUNT

LENGTH OF CONDITIONING TIME IS CALCULATED BASED ON CURRENT POLISHING RATE AND POLISHING RATE VARIATION AMOUNT

EXAMPLE:

WHEN
CURRENT POLISHING RATE X=1250
POLISHING RATE VARIATION RATE R=45,
CALCULATION IS CONDUCTED BY EMPLOYING THE BELOW PART OF THE CONVERSION TABLE BECAUSE
$1200 \leqq X \leqq 1300$ AND $0 \leqq R \leqq 50$.

X1=1300	T1=85	T3=80
X2=1200	T2=90	T4=85
	RA=0	RB=50

LENGTH OF CONDITIONING TIME IS CALCULATED BASED ON:
$TA = ((T2-T1) / (X2-X1)) \times (X-X1) + T1$
$TB = ((T4-T3) / (X2-X1)) \times (X-X1) + T3$
$T = ((TB-TA) / (RB-RA)) \times (R-RA) + TA$
AND IS ESMITATED T=83

FIG. 5

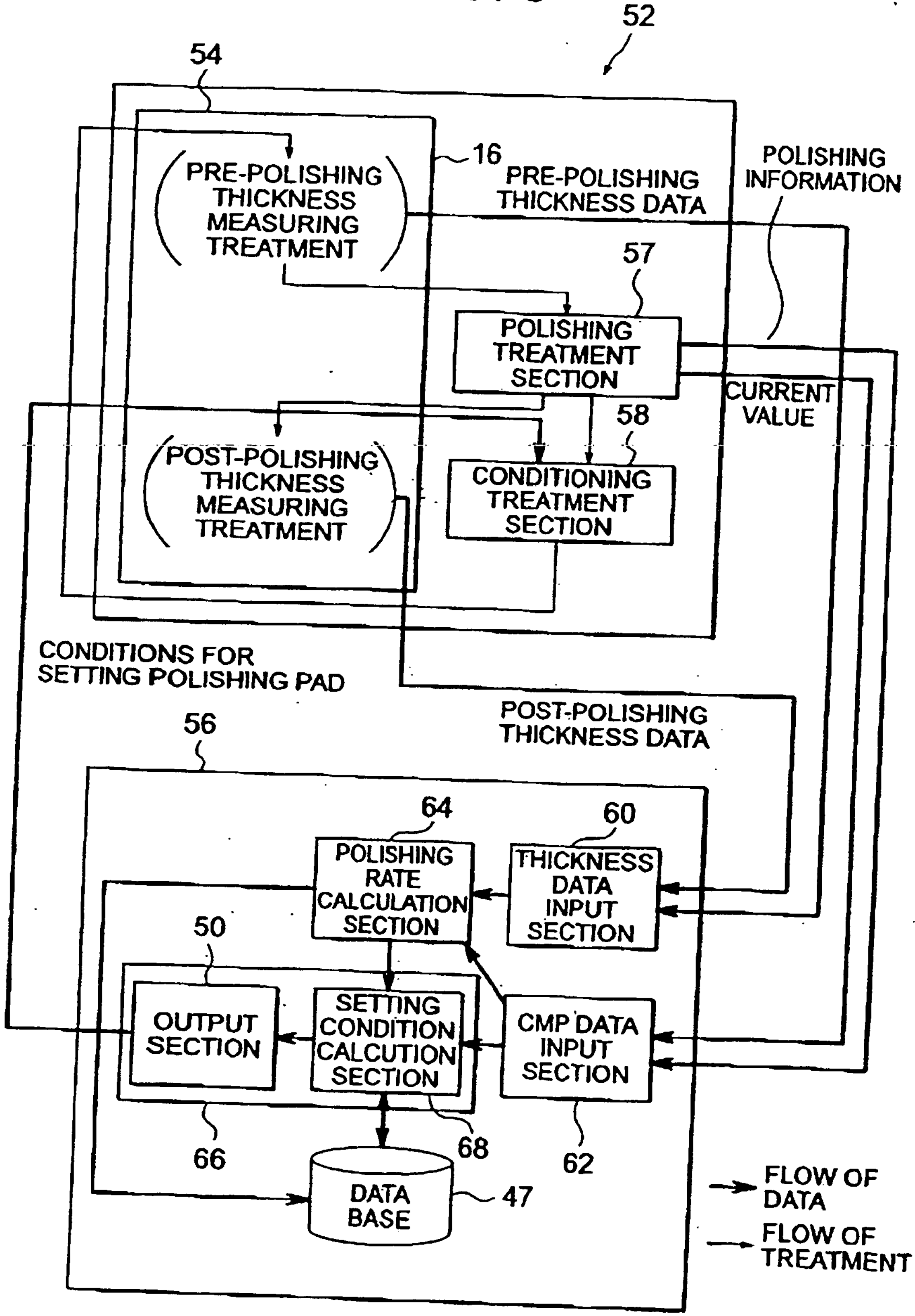
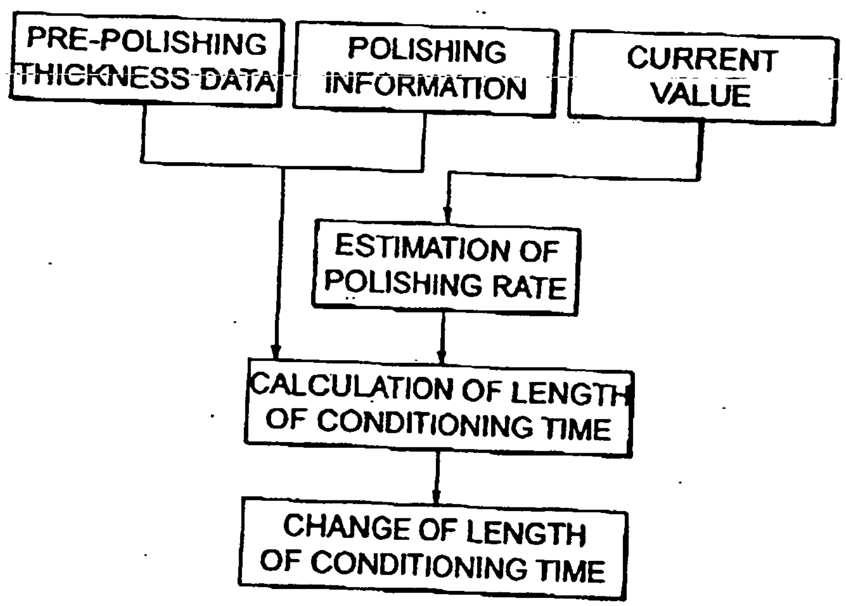
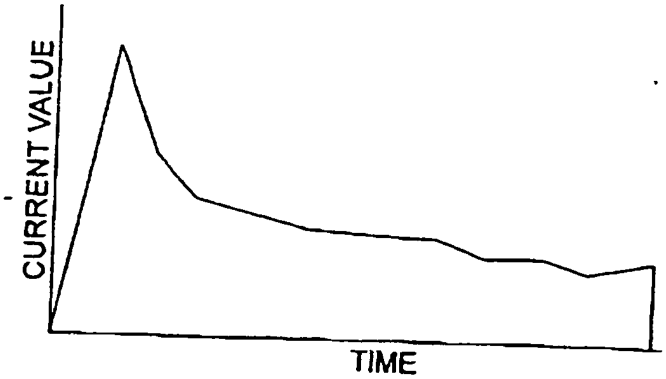

52
54
16
PRE-POLISHING THICKNESS MEASURING TREATMENT
PRE-POLISHING THICKNESS DATA
POLISHING INFORMATION
57
POLISHING TREATMENT SECTION
CURRENT VALUE
58
POST-POLISHING THICKNESS MEASURING TREATMENT
CONDITIONING TREATMENT SECTION
CONDITIONS FOR SETTING POLISHING PAD
POST-POLISHING THICKNESS DATA
56
64
POLISHING RATE CALCULATION SECTION
60
THICKNESS DATA INPUT SECTION
50
OUTPUT SECTION
SETTING CONDITION CALCUTION SECTION
CMP DATA INPUT SECTION
66
68
62
DATA BASE
47
FLOW OF DATA
FLOW OF TREATMENT

FIG. 6



PRE-POLISHING THICKNESS DATA
POLISHING INFORMATION
CURRENT VALUE
ESTIMATION OF POLISHING RATE
CALCULATION OF LENGTH OF CONDITIONING TIME
CHANGE OF LENGTH OF CONDITIONING TIME

FIG. 7



CHARACTERISTICS SUCH AS VARIATION AMOUNT AND INTEGRATION AMOUNT ARE EXTRACTED FROM CURRENT VALUES SUPPLIED TO TABLE MOTOR AND SPINDLE MOTOR

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CONVERSION TABLES ARE SELECTED FROM DATA BASE BASED ON KIND OF FILM AND PRODUCT NAME

KIND OF FILM:OXIDE FILM 1,PRODUCT NAME:12345

CURRENT INTEGRATION VALUE					
1600	80	75	70	65	60
1500	85	80	75	70	65
1400	90	85	80	75	70
1300	95	90	85	80	75
1200	100	95	90	85	80
1100	105	100	95	90	85
1000	110	105	100	95	90
	-100	-50	0	50	100

POLISHING RATE VARIATION AMOUNT

↓

LENGTH OF CONDITIONING TIME IS CALCULATED BASED ON CURRENT POLISHING RATE AND POLISHING RATE VARIATION AMOUNT

EXAMPLE:

WHEN
CURRENT POLISHING RATE X=1250
POLISHING RATE VARIATION RATE R=45,
CALCULATION IS CONDUCTED BY EMPLOYING THE BELOW PART OF THE CONVERSION TABLE BECAUSE
$1200 \leqq X \leqq 1300$ AND $0 \leqq R \leqq 50$.

X1=1300	T1=85	T3=80
X2=1200	T2=90	T4=85
	RA=0	RB=50

LENGTH OF CONDITIONING TIME IS CALCULATED BASED ON:

$TA = ((T2-T1)\ /\ (X2-X1))\ X\ (X-X1)\ +T1$

$TB = ((T4-T3)\ /\ (X2-X1))\ X\ (X-X1)\ +T3$

$T\ = ((TB-TA)\ /\ (RB-RA))\ X\ (R-RA)\ +TA$

AND IS ESMITATED T=83

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CHEMICAL-MECHANICAL POLISHING APPARATUS AND METHOD

The present invention relates to a chemical-mechanical polishing apparatus and method. A particular chemical-mechanical polishing apparatus to be described below by way of example in illustration of the present invention is able to polish a wafer by a given amount.

In the manufacture of a semiconductor device, it has previously been ~~proposed to employ a chemical-mechanical polishing apparatus (hereinafter~~ referred to as a "CMP apparatus"). It is important to keep the amount of polishing within a fixed range when the polishing is carried out using the CMP apparatus. The CMP apparatus previously proposed has a controller for controlling the length of polishing time.

An example of a previously proposed CMP apparatus will now be described by reference to Fig. 1 of the accompanying drawings, which shows by means of a block schematic diagram both an apparatus and a process.

The previously proposed CMP apparatus indicated at 10 in Fig. 1 has a polishing block 12 for polishing a film formed on a wafer, and a controller 14 for controlling the length of the polishing time.

The polishing block 12 includes a polishing treatment section 15 for polishing the film on the wafer, a thickness meter 16 for measuring the thicknesses of the film before and after a polishing operation, and a conditioning treatment section 18 having a dresser for setting a polishing

pad. The polishing pad (not shown), a polishing table (not shown) which rotates while holding the polishing pad, a wafer holder (not shown), which rotates the film while pressing the film on a wafer or wafers on to the polishing pad, and a time section (not shown) for measuring the length of the polishing time are included in the polishing treatment section 15.

The controller 14 includes a thickness data input section 21 for receiving film thickness data which is transmitted from the polishing block 12, a rate calculation section 22 for calculating both the polishing rate from the film thicknesses before and after the polishing operation, and the length of the polishing time, a time calculation section 23 for calculating the length of the polishing time for the next wafer, and an output section 24 for transmitting the calculated length of the polishing time to the polishing block 12.

In order to polish the film on the wafer by employing the previously proposed CMP apparatus 10, the film thickness before the polishing is first measured by the thickness meter 16 for measuring the film thicknesses, and the data obtained by this measurement (hereinafter referred to as "pre-polishing thickness data") is sent to the controller 14.

Then, a polishing treatment is carried out. Upon the completion of the polishing operation, the CMP apparatus 10 carries out a setting treatment.

The film thickness after polishing is then measured by means of the thickness meter 16, and the data obtained by this measurement (hereinafter referred to as "post-polishing thickness data") is sent to the controller 14. The controller 14 calculates both the current amount of polishing, based on

both the pre-polishing thickness data and the post-polishing thickness data, and the length of time required for the polishing treatment of the next wafer. The length of time thus determined is sent to the polishing block 12.

However, in the previously proposed CMP apparatus just described, the length of the polishing time always varies, because, for example, the conditions for setting the polishing pad are not constant. The required length of the polishing time for a single wafer increases with every wafer that is polished. The length of the polishing time is at its least immediately after the setting of the polishing pad. Thus, disadvantages have been observed, in that the amount of polishing of the wafer cannot be satisfactorily controlled, and in that the polishing pad is liable to be damaged and has a reduced life.

Features of a CMP apparatus to be described, by way of example in illustration of the present invention, are that the amount of polishing is more satisfactorily controlled, and that the polishing treatment is more stable than in the previously proposed arrangement.

A CMP apparatus to be described below by way of example in illustration of the present invention includes a polishing pad, a polishing table rotatable while holding the polishing pad, a wafer holder for pressing together a film on a wafer and the polishing pad, while the wafer is held, a dresser for setting the polishing pad each time after a specified number of the wafers have been chemically and mechanically polished, and a conditioning controller including a rate calculation section for calculating a polishing rate and an establishing section for establishing the conditions for

setting the polishing pad based on the calculated polishing rate.

In a particular CMP apparatus to be described below, by way of example in illustration of the present invention, after a predetermined number of the wafers has been polished, the setting conditions of the polishing pad can be suitably corrected or the conditions of the polishing pad can be maintained nearly constant, and the polishing can be properly conducted. Accordingly, the CMP apparatus to be described can provide a more stabilized polishing rate and a satisfactory control of the amount of polishing. Further, any damage that may be caused to the polishing pad is minimised. In arrangements to be described below by way of example in illustration of the present invention, it is preferable that the specified predetermined number of wafers is 1 or 2.

Arrangements which are illustrative of the present invention will now be described, by way of example with reference to Figs. 2 to 7 of the accompanying drawings, in which:

Fig. 2 is a block schematic diagram for use in describing a first CMP apparatus and a treatment process carried out therein,

Fig. 3 is a block schematic diagram for use in describing in more detail the treatment process of the first CMP apparatus shown in Fig. 2,

Fig. 4 is a table for use in describing aspects of the treatment process of the first arrangement shown in Fig. 2,

Fig. 5 is a block schematic diagram for use in describing a second CMP apparatus and a treatment process carried out therein,

Fig. 6 is a block schematic diagram for use in describing the

treatment process of the second arrangement shown in Fig. 5, and

Fig. 7 is a table for use in describing aspects of the treatment process of the second arrangement shown in Fig. 5.

In describing the CMP apparatus and the steps in the treatment carried out by the CMP apparatus of Fig. 2, similar elements to those described in relation to the arrangement of Fig. 1 will be indicated by the same reference numerals and no further detailed description of them will be given.

A CMP apparatus 30 shown in Fig. 2 has a polishing block 32 and a conditioning controller 34 for establishing the setting conditions of a polishing pad. The conditioning controller 34 is connected to the polishing block 32 by means of a signal line for supplying and receiving signals.

The polishing block 32 includes a treatment section 36 for polishing a film on a wafer, a thickness meter 16 for measuring the film thicknesses before and after the polishing operation and a conditioning treatment section 38 having a dresser for setting a polishing pad (not shown). The polishing pad, a polishing table (not shown), a wafer holder (not shown), and a timer section (not shown) for measuring the length of the polishing time are included in the treatment section 36.

The conditioning controller 34 includes a thickness data input section 40 for receiving film thickness data from the thickness meter 16 and a CMP data input section 42 for receiving polishing information, such as the length of the polishing time, as a polishing instruction from the polishing block 32.

The conditioning controller 34 further includes a calculation section 44

for calculating a polishing rate based on the data received from both of the input sections 40 and 42, an establishing section 46 for establishing the conditions for setting the polishing pad based on the calculated polishing rate, and a data base 47 for storing data. The establishing section 46 includes a calculation section 48 for calculating the required length of the setting time based on the polishing rate and the polishing information, and an output section 50 for transmitting the calculated length of the setting time to the conditioning treatment section 38. The data base 47 includes conversion tables for the calculation of the required setting time for each of the combinations of the kinds of films and products, and the calculation section 48 carries out the transfer of the data to the data base 47.

A process of polishing carried out by the CMP apparatus 30 will now be described.

The pre-polishing thickness data relating to the film on the wafer which is to be subjected to the CMP treatment is measured by the thickness meter 16, and transmitted to the thickness data input section 40.

Then, the wafer is sent to the polishing block 32 where it receives the polishing treatment. During the treatment, the polishing information (the length of polishing time and the degree of pressure on a spindle) and the product information (the kind of films and the product name of the semiconductor device) are transmitted to the CMP data input section 42.

The wafer, upon the completion of the polishing treatment, is sent to the thickness meter 16 where the film thickness after the polishing operation is measured. Th post-polishing thickness data is transmitted to the

thickness data input section 40.

Thereafter, the calculation section 44 calculates the current polishing rate based on the pre-polishing thickness data and the post-polishing thickness data received by the thickness data input section 40 and the length of the polishing time received by the CMP data input section 42.

The calculation section 48 calculates both the polishing rate variation value, which is the difference between the current polishing rate and the previous polishing rate, and the required length of setting time based on the current polishing rate, the polishing rate variation value and the conditioning time conversion data tables of the data base 47 (refer to Fig. 3).

The calculation of the required length of the setting time can be carried out as follows.

The calculation section 48 extracts the required information from the data base 47 including the data stored in the conversion data tables in relation to the product information, that is, in relation to the kind of the film in connection with the wafer being treated and the product name of the semiconductor. The required length of the setting time is calculated by means of an interpolation based on the required portions of the information extracted from the conversion data tables, the current polishing rate and the polishing rate variation value.

The output section 50 transmits the calculated length of the setting time to the polishing block 32 which carries out a setting treatment based on the received length of the setting time.

The calculated data and the data received from the polishing block 32

are stored in the data base 47.

In the present arrangement being described, the setting conditions of the polishing pad can be maintained nearly constant, and the amount of the polished film on the wafer is nearly constant and is much more stabilized compared with that of the previously proposed arrangement. Further, the damage caused to the polishing pad is much less than that caused in the previously proposed arrangement.

A similar result can be obtained by calculating in a similar way the pressure conditions on the conditioning head by the calculation section 48, and by modifying the setting conditions in accordance with the calculated pressure conditions.

In the first described arrangement of which the treatment can be seen from the table of Fig. 4, the calculation section 48 calculates a required length of setting time by employing the following equations.

$$TA= \{(X - X1)/(X2 - X1) \times (T2 - T1) + T1 \qquad (1)$$

$$TB = \{(X - X1)/(X2 - X1) \times (T4 - T3) + T3 \qquad (2)$$

$$T = \{(R - RA)/(RB - RA) \times (TB - TA) + TA \qquad (3)$$

In these equations, X is a current polishing rate, X1 and X2 are an upper limit and a lower limit of a range in which X can exist, respectively, among the polishing rates included in the setting time calculation table. R is a polishing rate variation value, RA and RB are an upper value and a lower limit of a range in which R can exist, respectively, among the polishing rate variation values included in the setting time calculation table. T1, T2, T3 and T4 are required lengths of setting times corresponding to X1 and RA, X2

and RA, X1 and RB, and X2 and RB, respectively.

In this first described arrangement, the calculated polishing rate X was 1250, and the polishing rate variation amount R was 45. Based on these values, X1=1300, X2=1200, T1=85, T2=90, T3=80, T4=85, RA=0 and RB=50 were obtained to calculate a required length of setting time T=83.

A CMP apparatus 52 of the second arrangement shown in Fig. 5 is different from the CMP apparatus 30 of the first described arrangement in that after the polishing of the wafer, the film thickness measurement and the setting of the polishing pad are carried out simultaneously. In describing the second arrangement of Fig. 5, similar elements to those of the first arrangement of Fig. 2 are denoted by the same reference numerals and they will not be described in detail.

The CMP apparatus 52 includes a polishing block 54 which polishes a film on a wafer, and a conditioning roller 56 for establishing the setting conditions of a polishing pad. The conditioning controller 56 is connected to the polishing block 54 by means of a signal line for supplying and receiving signals.

The polishing block 54 includes, in a similar way to the polishing block 32 of the first described arrangement of Fig. 2, a polishing treatment section 57 for polishing the film on the wafer, the thickness meter 16 for measuring the film thicknesses before and after the polishing operation, and a conditioning treatment section 58 having a dresser for setting the polishing pad (not shown). The polishing treatment section 57 includes the polishing pad, a polishing table (not shown), a wafer holder (not shown), and a device

for measuring the length of the polishing time (not shown). The polishing block 54 further includes a motor table for rotating the polishing table, and a motor having a spindle for rotating the wafer holder (both of which are not shown).

The conditioning controller 56 includes, in a similar way to the conditioning controller 14, a thickness data input section 60 and a CMP data input section 62.

The conditioning controller 56 further includes a calculation section 64 which calculates the polishing rate from the values of the film thicknesses before and after polishing and the length of the polishing time, and calculates the polishing rate, based on polishing information received from the polishing block 54 during the polishing, an establishment section 66 for establishing the setting conditions of the polishing pad based on the calculated polishing rate and a data base 47 for storing the data. The calculation section 64 calculates the polishing rate based on the values of the current supplied to the motor having a table, and the motor having a spindle, and on the length of the polishing time. The establishment section 66 includes a setting conditions calculation section 68 for calculating a required length of the setting time based on the polishing rate and a polishing instruction, and an output section 50 for transmitting the required length of the setting time to the conditioning treatment section 58. The data base 47 includes conditioning time conversion tables similar to those of the first example described with reference to Fig. 2, and the setting conditions calculation section 68 carries out the transfer of the data to the data base 47.

The process of polishing carried out by CMP apparatus 30 will now be described referring to Fig. 6.

The pre-polishing thickness data of the film on the wafer which is to be subjected to the CMP treatment are measured by means of the thickness meter 16, and transmitted to the film thickness data input section 60.

Then, the wafer is sent to the polishing block 54 and receives the polishing treatment. During the treatment, polishing information (the length of the polishing time and the degree of pressure on the spindle), the values of the current supplied to the motor having a table and the motor having a spindle, and product information (the kind of film and the product name of a semiconductor device) are transmitted to the CMP data input section 62.

Upon the completion of the polishing treatment, the wafer is sent to the thickness meter 16 and the film thickness after the polishing operation is measured. The post-polishing thickness data is transmitted to the film thickness data input section 60.

Simultaneously therewith, the polishing rate calculation section 64 calculates the current polishing rate based on the values of the current supplied to the motor having a table and the motor having a spindle and on the length of the polishing time, and estimates the conditions for the polishing pad.

The conditioning time conversion data tables associated with the particular kind of the film currently being treated and the product name of the semiconductor are extracted from the data base 47 and received.

Thereafter, a required length of setting time is calculated and

transmitted to a conditioning treatment section 58 in a similar way to the first described arrangement of Fig. 2.

Upon the completion of the measurement of the film thickness after the polishing operation, the polishing rate calculation section 64 calculates the precise value of the current polishing rate based on the pre-polishing thickness data and the post-polishing thickness data received by the film thickness data input section 60 and the length of the polishing time received by the CMP data input section 62, and stores the precise data in the data base 47. The precise data is employed as data for improving the accuracy of a subsequent setting treatment.

Similar improved effects to those of the example described with reference to Fig. 2 can be obtained by means of the arrangement of Fig. 5. The amount of polishing can be sufficiently controlled even if the CMP apparatus 52 does not have the thickness meter 16.

With regard to the second arrangement illustrated in Fig. 5, reference is made to a graph showing the relation between the length of polishing time and the values of the current of a motor having a table and a motor having a spindle, and a polishing rate is calculated based on the graph and in accordance with the procedure shown in Fig. 7. The calculated polishing rate X was 1250, and a variation amount R of the polishing rate was 45. Based on these values, the results X1=1300, X2-1200, T1=85, T2=90, T3=80, T4=85, RA=0 and RB=50 were obtained, similar to those of the first arrangement described with reference to Fig. 2, to calculate a required length of setting time T=83.

Thereafter, the precise value of the polishing rate was calculated based on the pre-polishing thickness data and the post-polishing thickness data and was stored in the data base 47.

The above arrangements have been described only as examples, and the scope of the protection sought is not limited to the above illustrative arrangements.

It will be understood that, although particular arrangements have been described, by way of example in illustration of the invention, variations and modifications thereof, as well as other arrangements, may be conceived within the scope of the appended claims.

CLAIMS

1. A chemical-mechanical polishing (CMP) apparatus including a polishing pad, a polishing table rotatable while holding the polishing pad, a wafer holder so arranged that a film on a wafer and the polishing pad are pressed together while the wafer is held, and a dresser for setting the polishing pad each time after a specified predetermined number of the wafers has been chemically and mechanically polished, a conditioning controller including a rate calculation section for calculating a polishing rate and an establishing section for establishing conditions for setting the polishing pad based on the calculated polishing rate.

2. A CMP apparatus as claimed in claim 1, in which the rate calculation section calculates the polishing rate based on film thicknesses before and after the polishing of the film and on the length of the polishing time.

3. A CMP apparatus as claimed in claim 1, in which the polishing rate calculation section calculates the polishing rate based on the current/ power required for rotating the polishing table and the wafer holder during the polishing and the length of polishing time.

4. A CMP apparatus as claimed in claim 1, wherein the condition

establishing section establishes the required length of the setting time in accordance with the correlation between the polishing rate and the required length of the setting time.

5. A CMP apparatus as claimed in claim 4, in which the correlation is determined from a graph.

6. A CMP apparatus as claimed in claim 4, in which the correlation is determined from a table.

7. A CMP apparatus as claimed in claim 1, in which the condition establishing section establishes a required pressing force of a dresser upon the polishing pad in accordance with the correlation determined in advance between the polishing rate and the required length of the setting time.

8. A CMP apparatus as claimed in claim 7, in which the correlation is determined from a graph.

9. A CMP apparatus as claimed in claim 7, in which the correlation is determined from a table.

10. A CMP apparatus as claimed in claim 9, in which the condition establishing section establishes the conditions by the interpolation of the correlation determined from the table.

11. A method of operating a CMP apparatus as claimed in claim 1 substantially as described herein with reference to Figs. 2-4 or 5 to 7 of the accompanying drawings.

12. A CMP apparatus as claimed in claim 1 substantially as described herein with reference to Figs. 2-4, or 5 to 7, of the accompanying drawings.